Journal of the Royal Society of Western Australia, 85:129-132, 2002

Cost effectiveness and data-yield of biodiversity surveys

L Bisevac & J Majer

Department of Environmental Biology,
Curtin University of Technology,
GPO Box U 1987, Perth WA 6845
email: bisevac@webace.com.au

Abstract

The most common approach to general biological surveys is based on various measures of plant communities in the investigated area. Fauna are not usually considered, and if animals are included the emphasis is generally on the more "charismatic" vertebrates. Invertebrates are ideally suited for conveying information about the environmental status of an area. This paper makes a comparison of the logistics of performing plant, vertebrate and invertebrate samples in a biological survey. Evidence is presented which indicates that the inclusion of invertebrates in surveys can contribute to data on physical factors, as well as on plant and vertebrate communities. Some invertebrate taxa are richer in species than the corresponding vertebrate fauna. In terms of trends in species richness across sites, and also in terms of changes in community composition, certain invertebrates portray a better interpretation of changes in habitat than do the vertebrates. It is suggested that invertebrates can provide a cost-effective means of generating information on the environmental status of an area.

Keywords: biological survey, community composition, cost-effectiveness, invertebrates

Introduction

Biological surveys are carried out to prepare environmental impact statements, as part of general biological surveys to assess the impact of disturbance or, conversely, to assess the effectiveness of rehabilitation programmes. There has been a repeated tendency to concentrate on plants and, if fauna are considered, the vertebrate fauna. There are compelling reasons why invertebrates should be included in these biological surveys (Abbott 1989; Hutson 1989; Majer 1990).

In this paper, the possibility of using selected invertebrate taxa in biological surveys, along with plants and vertebrates, is evaluated. Specifically, this study evaluated the value of sampling this diverse range of organisms as part of Completion Criteria schedules using a Western Australian mineral sand mine as a case study (Eneabba; Iluka Resources). The results nevertheless have applicability to other types of biological surveys.

A chronosequence of 10 restored areas and four heath controls was selected and sampled by plant, invertebrate and vertebrate sampling protocols. Invertebrate samples were sorted in the laboratory to broad taxonomic (ordinal) levels and, for a selection of groups representing different trophic levels, to species. Plants and vertebrates were surveyed in the same plots by independent consultants. The entire procedure was timed, and the period of time allocated to sampling, ordinal level sorting, sorting of each individual taxonomic groups and data processing, were recorded. The ultimate aim of the study was to assess the time- and cost-effectiveness of sampling the various taxa and the data-yield that can be derived from them.

This paper was presented in similar form at the Workshop on the Co-ordination and Integration of Terrestrial Vertebrate Fauna Survey Database for Western Australia, held on April 5, 2002, at the University of Western Australia

Material and methods

A 100 m transect was established in the centre of each rehabilitated plot and in controls. Three methods of collection were used; pitfall traps, suction, and litter sampling. Twenty one pitfall traps, consisting of 4 cm internal diameter plastic tubes containing 50 ml of alcohol/glycerol (70/30 v/v) were buried level to the ground at 5 m intervals along the transect. Traps were left open for 7 days and then taken out for sorting. Along each transect, 10 suction samples were taken, each covering an area of 50 m^2. Arthropods were vacuumed off the plants for 10 minutes per sample, using a modified garden leaf vacuum machine and then placed in containers of 70% alcohol for later sorting. Litter samples were collected along transects and placed in 3 kg polyethylene bags (the same amount of leaf litter was collected from each plot). After returning to Perth, the samples were placed in Tullgren funnels. Temperatures in funnels were gradually increased from 25 to 40 °C over a one week extraction period. All extracted invertebrates were placed in 70% alcohol until further sorting. All sampling methods were performed six times, between August 1997 until November 1998, at three monthly intervals.

Plants were surveyed by Mattiske Consulting Pty Ltd in October and November 1998 in a range of plots. Between 100 and 140 quadrats were set at each plot, and plants were mostly identified in the field; species that could not be identified in the field were collected for later identification. Data presented here are only for those rehabilitated and control plots that are the same as the ones used for invertebrate sampling; data for plants are not available for one of the control plots.

Vertebrate animals were collected by Halpern Glick Maunsell Pty Ltd on two separate occasions, October 1997 and February 1998, as a part of a larger fauna monitoring programme. Fauna was surveyed at five of the rehabilitated and three of the control plots. Ground vertebrate fauna was collected at each plot using 10 pitfall traps, 10 bucket traps, 16 Elliott traps and four wire cage traps. The traps were arranged in two transects, one that ran north-south, and another that ran east-west, forming a T-configuration. Data on the presences of bird species were obtained by systematic censuses at each plot.

All parts of the work were timed and expressed as time (in hours) per plot required to perform each task. In this way, the time and ultimately the cost involved in performing surveys using each of these taxa can be estimated and the data-yield from each of these groups can be compared.

Data-sets were analysed using the PATN computer package (Belbin 1995). Hierarchical cluster analysis (UPGMA) was used to examine patterns of species composition in the data matrices of each taxon. The association measure Two Step (Belbin 1980) was used to determine the quantitative relationship between each pair of species, and the Czekanowski (1932) measure was used to compare the plots according to their similarity. An ordination of the plots for each taxon was created using results from these analyses. Cross-taxon analysis involved the estimation of the influence of each taxon on the overall community composition (McKenzie *et al.* 2000). Databases of all taxa were used as sub-sets and were combined to create the community matrix. The community matrix was based on four invertebrate taxa (springtails, spiders, beetles and ants), plants, birds and terrestrial vertebrates (amphibians, reptiles and mammals) from a total of eight plots (five rehabilitated and three control plots). Using Pearson product-moment correlation, the relationship between each pair of taxa was calculated. By doing this it was possible to derive similarity matrices for each data sub-set, as well as for the combined dataset. These matrices were represented as linear similarity vectors. This correlation matrix was converted to a dissimilarity matrix and Semi-strong Hybrid Scaling was used to reduce dimensionality of this matrix, so that relationships between different taxa datasets could be displayed in three dimensions. Here, the Minimum Spanning Tree was superimposed to indicate the nearest-neighbour linkages in the ordination space. In order to provide some extrinsic measure of distance across the ordination space, 1000 uniform random matrices were generated and plotted in the same ordination space. The resulting diagram provided a measure of how much each taxon reflected the composition of another taxonomic group, and also of the congruence of each taxonomic group to the combined data-set, which itself is our best estimate of the overall community composition.

Results and Discussion

The times taken to conduct the various invertebrate components of the Eneabba invertebrate survey, as well as to sort and tabulate the material, are shown in Table 1. The mean time required to sample the entire invertebrate material at Eneabba was 2.3 h per plot, comprising; 1.1 h for pitfall traps, 1 h for suction samples, and 0.2 h for litter samples. The time needed to identify material to ordinal level was 3.5 h per plot, comprising; 2.5 h for pitfall traps, 0.4 h for suction samples, and 0.6 h for litter samples. The ratio of time spent in collecting material to time spent in the laboratory identifying and tabulating material to ordinal level was 1:1.5. The highest ratio was for litter samples (1:3), since much of the material was microscopic. The ratio for pitfall traps was 1:2.3. But, because relatively few animals were obtained in suction samples, the time spent in the laboratory processing this material was less than the time in the field (1:0.4).

Table 1 shows the number of species of plants, selected invertebrates and vertebrates obtained in the

Table 1

Numbers of species or orders sampled during five seasons in 10 restored plots and four heathland control plots at the Iluka mineral sand mine, near Eneabba, Western Australia. Also shown is the mean time to sort/identify each group to morpho-species or species level.

Taxon	Total morpho-species or orders	Time to sample one plot (hr)[a]	Time to sort one plot (hr)[b]	Total time (hr)	Species or orders per hr
Plants	194	3.0	2.4	5.4	35.9
Arthropoda – Orders	27	2.3	3.5	5.8	4.7
Crustacea – Isopoda	3	2.3	0.2	2.5	1.2
Chilopoda	3	2.3	0.2	2.5	1.2
Collembola	22	2.3	11.1	13.4	1.6
Chelicerata – Araneae	96	2.3	4.3	6.6	14.6
Insecta – Coleoptera	172	2.3	6.3	8.6	20.0
Insecta – Formicidae	86	2.3	7.1	9.4	9.1
Vertebrata – Amphibia	9	7.0	1.0	8.0	1.1
Vertebrata – Reptilia	15	7.0	2.5	9.5	1.6
Vertebrata – Aves	47	4.0	0.0	4.0	11.8
Vertebrata – Mammalia	4	7.0	1.0	8.0	0.5

[a] within the invertebrate and vertebrate groups, the field times collectively cover all groups, rather than being cumulative times.
[b] times to sort invertebrate groups to species assumes that they have already been sorted to order

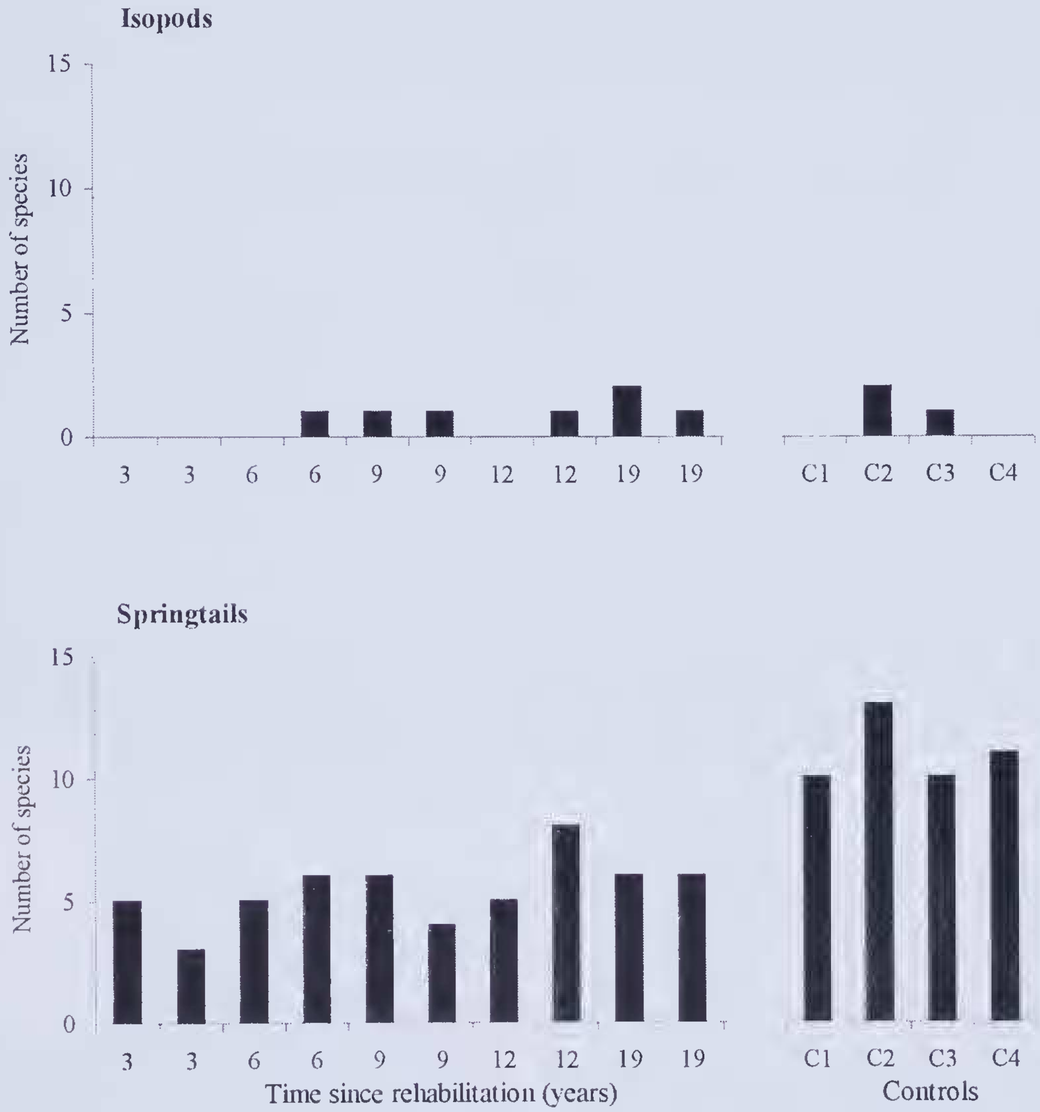

Figure 1. Comparisons between species richness of isopods and springtails on rehabilitated plots of different age with control plots.

investigations. It also shows the mean field time taken to sample and sort/identify these taxa from a plot. Although plants were the most diverse group, beetles, spiders and ants were almost as species rich. Birds were reasonably diverse, but reptiles, amphibians and mammals were represented by few species. These trends were also represented in the number of species obtained per hour of effort.

The data-yield in terms of numbers of species sampled per unit effort is of importance, because diverse samples are likely to yield more information about restoration success than less diverse taxa; taxa with low numbers of species can produce spurious results. This is well illustrated by the chronosequence data in Fig 1, which indicates that although a discernable trend is evident for a species-rich group such as the springtails (Collembola), it is impossible to detect any consistent trends with a group where few species were found, such as the slaters (Isopoda).

Relationships and correlation coefficients between examined taxa and "overall community composition" are shown in Fig 2. Plants, ants and beetles were the taxa with the highest correlation with the overall community composition. Terrestrial vertebrates (amphibians, reptiles and mammals), although not represented by a very high number of species, proved to be relatively close to the overall community composition, with a high correlation coefficient. For birds and spiders, the closest neighbour in ordination space was not overall community; birds showed highest correlation to springtails, and spiders to ants. This suggests that, despite high numbers of species in these taxa, birds do not appear to be reliable indicators of the community in which they occur. Alternatively, their pattern of occurrence across the plots may be different from that of some of the other taxa that we considered.

The high invertebrate diversity has implications for the types of statistical analyses that may be performed on the data. Collections that contain high numbers of species lend themselves to robust data analyses by such techniques as classification, ordination and other multivariate analyses. Trends in diversity indices also

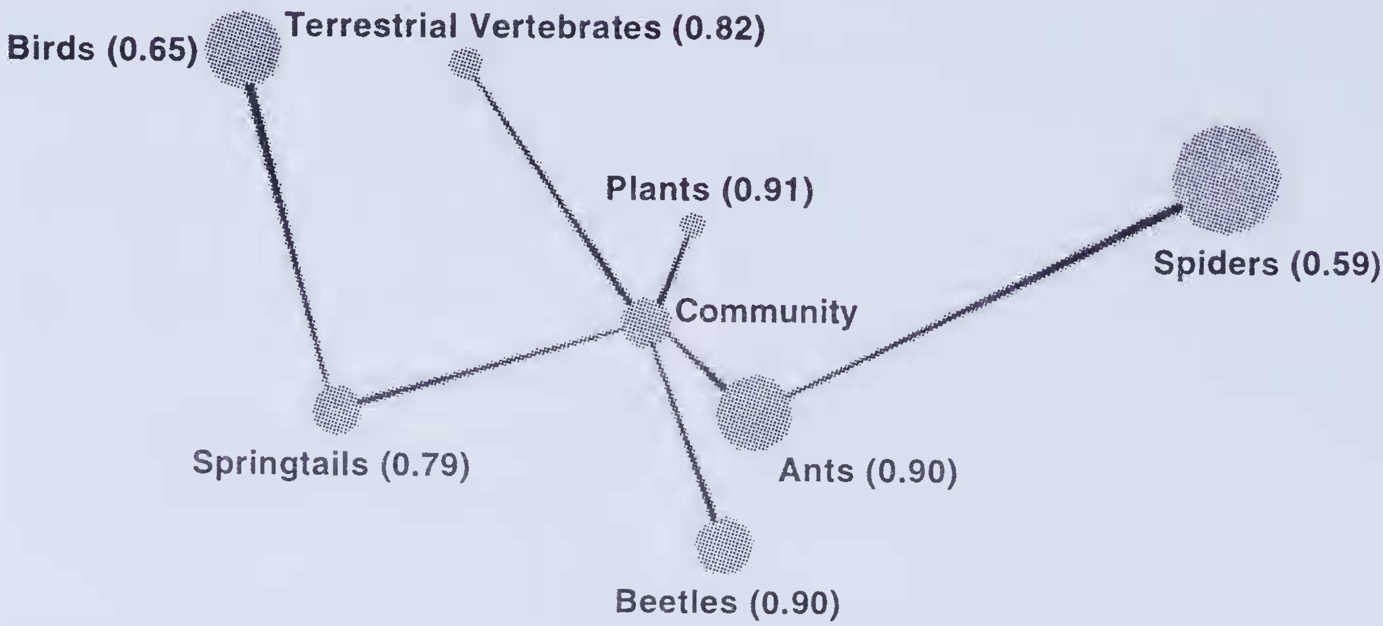

Figure 2. Comparison of the community patterns derived from seven taxa sub-sets, and from the total data-set. A matrix of correlation coefficients was compiled from a pairwise comparison of the relevant transect similarity matrices. Results are displayed in three-dimensions using Semi-strong Hybrid Scaling (stress = 0.07). Minimum Spanning Tree linkages are superimposed to indicate nearest neighbours in community space. The correlations of each taxon with the community are shown in brackets.

tend to be more meaningful in cases where high numbers of species are involved; variations in low-diversity taxa between sites can yield serendipitous results.

There is also the issue of how well each taxon represents differences, or changes, in community composition between plots. The invertebrate data reported here prove themselves to be cost-effective to gather and potentially high in information content. Being the most diverse members of the animal kingdom, their inclusion in surveys can contribute to data on physical factors and plant and vertebrate communities in habitats. As well as strengthening the conclusions reached from a study of these aspects alone, invertebrate data can provide an indication of the degree of re-establishment of ecosystem functioning.

Acknowledgements: The authors wish to thank Iluka Resources Ltd (formerly RGC Mineral Sands Ltd) for funding this project. We also wish to thank Mattiske Consulting Pty Ltd and Halpern Glick Maunsell Pty Ltd for participating in this survey. Special thanks to Norm McKenzie from CALM for his help with the ordination and cross-taxon congruence analysis.

References

Abbott I 1989 The influence of fauna on soil structure. In: Animals in Primary Succession: The Role of Fauna in Reclaimed Lands (ed J D Majer). Cambridge University Press, Cambridge, 39–50.

Belbin L 1980 TWOSTEP: A program incorporating asymmetric comparisons that uses two steps to produce a dissimilarity matrix. CSIRO Division of Land Use Research Technical Memorandum 80/9. CSIRO, Canberra.

Belbin L 1995 PATN Technical Reference. CSIRO Division of Wildlife and Ecology, Canberra.

Czekanowski J 1932 Coefficient of racial likeness, und durchschnittliche differenz. Anthropologischer Anzeiger 9:227–249.

Hutson B R 1989 The role of fauna in nutrient turnover. In: Animals in Primary Succession: The Role of Fauna in Reclaimed Lands (ed J D Majer). Cambridge University Press, Cambridge, 51–70.

Majer J D 1990 Rehabilitation of disturbed land: Long term prospects for the recolonization of fauna. Proceedings of the Ecological Society of Australia 16:509–519.

McKenzie N L, Keighery G J, Gibson N & Rolfe J K 2000 Patterns in the biodiversity of terrestrial environments in the southern Carnarvon Basin, Western Australia. Records of the Western Australian Museum Supplement 61:511–546.